

Variable frequency drive trainer kits for electronic control system subjects in vocational secondary schools

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ABSTRACT

The objective of this study is to create a variable frequency drive (VFD) trainer kit, assess the practicality of the developed VFD educational tool, and evaluate its impact on the academic performance of industrial electronic engineering students, particularly in the area of electronic control systems. The study utilizes the ADDIE model and customized to meet the requirements and consists of the following phases: analysis, design, development, implementation, and evaluation. There were 130 respondents consisting of 122 vocational students, 1 industry expert/practitioner in the field of VFD, 1 vocational training center instructor, 4 vocational teachers, and 2 lecturers. Data were collected using questionnaires with 4 Likert scales from strongly agree to strongly disagree, feasibility assessment sheets from media experts and material experts, interviews, and electronic control system learning outcomes tests. The learning media receives a "highly feasible" and the job sheet obtains 67 "highly feasible". Moreover, the level of effectiveness of the learning media receives a score of 0.724, indicating high effectiveness. Therefore, they have proven to be effective in enhancing student learning outcomes and developing their proficiency in controlling the speed of electric motors. This will help bridge the gap between the industry's skill requirements and the skills taught in schools.

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1. INTRODUCTION

Vocational secondary school (VSS) strives to cultivate a workforce that is proficient and capable of thriving in the corporate realm, and seamlessly transitioning into the industrial sector [1], [2]. However, it is worth noting that within the community, there persists a perception that VSS is a secondary option [3]. This is further facilitated by the government through the implementation of programs aimed at promoting the

expansion of vocational schools. The objective is to expedite the development of a skilled and competitive workforce at the intermediate level, which will subsequently contribute to the overall growth of the national economy [4], [5]. Vocational students engage in practical activities that align with industry demands in a professional manner [6], [7]. Furthermore, VSS educators also have a crucial role in facilitating the integration of 21st century learning methodologies [8] that focus on students' technical proficiencies, competencies, and capabilities through hands-on vocational training, preparing them for future employment upon graduation from VSS [9]–[11].

The VSS are intended to cultivate self-reliant graduates who are prepared for the workforce. However, it is unfortunate that VSS graduates currently contribute to the highest unemployment rate in Indonesia [2], [12]. Based on data from the Central Bureau of Statistics of the Republic of Indonesia, in August 2022, the number of unemployed individuals attributed to graduates of VSS was 2,478,173 [13]. Notably, in the province of Banten, VSS graduates accounted for 13.52% of the overall unemployment rate in the province [14]. The elevated unemployment rate among vocational graduates can be attributed to various factors, one of which is the disparity between the skills imparted in educational institutions and the skills demanded by the industry [15]–[20]. Teachers at VSS No. 1 Cilegon City, who specialize in industrial electronics engineering, have reported that students are not being taught electric motor speed regulation skills due to a lack of available learning materials. However, according to the Indonesian National Work Competency Standards (number 268 of 2007 and 398 of 2014), expertise in electric motor speed regulation is necessary for individuals aspiring to become conveyor operators and maintainers of semi-automatic change over (SACO) or automatic change over (ACO) medium-voltage cubicle installations [21]–[23].

One of the contributing factors to the high unemployment rate among VSS graduates is the lack of alignment between the abilities possessed by these graduates and the skills demanded by the business [12], [17]. Variable frequency drive (VFD) is utilized in industrial settings for multiple purposes, including controlling the centrifugal pumps [24], [25], regulating the speed of the conveyor and motor speed [26], generate 24-stepped voltage waveform [27], and speed limit controlled [28]. Hence, it is crucial to engage in practical learning [18] through the utilization of VFD training kits in order to acquire competencies that align with the requirements of the industry.

According to the Indonesian National Work Competency Standard regulations 268 of 2007 and 398 of 2014, as well as interviews with teachers, it is evident that there is a lack of specialized knowledge and resources in schools and industry regarding teaching material on regulating the speed of electric motors. The electric motor can be modified using VFD electronic components, to operate fans, pumps, compressors, and other devices at different speeds [29]. A VFD is an electronic device that can efficiently and rapidly adjust the torque and rotational speed of an induction motor over a large range. It also has the capability to regulate the speed of the motor [30]. VFD also offers technology management and enhances power quality [31]. Given the issues and ideas offered, it is intriguing to explore and go deeper into significant matters. This study centers on the development of VFD trainer kits as educational tools for learning about ECS. It aims to assess the viability of the generated VFD trainer kits for student use and evaluate their usefulness in enhancing student learning outcomes in ECS subjects.

2. RESEARCH METHOD

2.1. Research design

The research methodology employed is research and development (R&D), with the objective of creating, manufacturing, and evaluating the efficacy of a product [1]. The research methodology employed is the ADDIE approach model, as suggested by Branch [32]. Figure 1 illustrates the ADDIE model, which encompasses the stages of analyze, design, develop, implement, and evaluate. At each stage, it is necessary to make adjustments to the product in order to enhance its quality. ADDIE is a technique that serves as a guiding framework for complicated situations, making it well-suited for the development of student-centered learning media [32].

The first step in this method is analyze. The problem that exists in Indonesia is still the high unemployment rate of VSS graduates, one of the factors is caused by the incompatibility of the skills needed by industry with the skills taught in schools. For example, the field of expertise in industrial electronics engineering at VSS No.1 Cilegon City has not taught students the expertise of regulating the speed of electric motors, while according to the regulations of the Indonesian National Work Competency Standard number 268 of 2007, 398 of 2014 the expertise of regulating the speed of electric motors is one of the knowledge needed, so that learning media for regulating the speed of electric motors is needed to reduce the gap between school with industry.

The initial phase of this approach is doing an analysis [1]. In Indonesia, a pressing issue persists: the elevated unemployment rate among graduates of VSS [33], [34]. One of the contributing elements to this problem is the lack of alignment between the skills required by industries and the capabilities imparted in

educational institutions. For instance, the industrial electronics engineering program at VSS State No. 1 Cilegon City does not include instruction on the skill of controlling the speed of electric motors. However, the Indonesian National Work Competency Standard regulations, specifically number 268 of 2007 and 398 of 2014, state that the ability to regulate the speed of electric motors is a necessary knowledge. Therefore, it is necessary to develop learning materials that cover the topic of regulating the speed of electric motors in order to bridge the gap between the school curriculum and industry requirements. The subsequent phase is design, comprising three components: developing a VFD training kit display design [24]–[35], creating a jobsheet of VFD trainer kit [36]–[41] and constructing assessments to measure student learning results for both pretest and posttest [42]–[46].

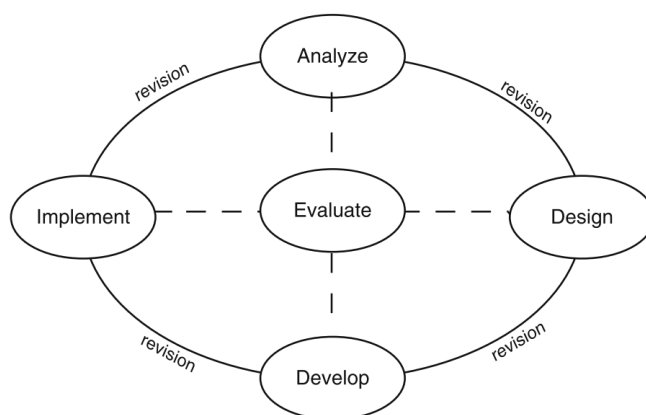


Figure 1. ADDIE model

The development stage [47], involves four distinct stages: installing each component on the acrylic panel, creating the VFD body trainer kit, integrating the acrylic panel with the VFD body trainer kit, and producing a VFD learning jobsheet. The jobsheet serves as a comprehensive guide for students, outlining the use of the VFD trainer kit and encompassing four unique tasks [36]. Subsequently, a feasibility assessment is conducted by media specialists and material specialists, utilizing the predetermined criteria outlined in Table 1. Each component is labeled with its matching name, symbols, and further information, all attached to the acrylic panel. This design will enhance the usability and maintenance of VFD trainer kits [48]. The VFD trainer kit consists of several components such as MCB, relay, push button, selection switch, potentiometer, magnetic contactor, time delay relay (TDR), indicator light, and VFD. This learning media employs VFD technology, allowing for the precise modification of the rotational speed of the induction motor across three discrete speeds [49].

During the implementation stage [48], students are initially assessed through multiple-choice questions to determine their pretest results, which reflect their initial abilities. Subsequently, students are provided with an explanation of the material concerning the regulation of electric motor speed using VFD. Following this, students engage in hands-on practical learning using VFD trainer kits, with jobsheets serving as instructional guides. The last stage is evaluate [50]–[55], when students use the trainer kit and VFD learning jobsheet, then students do pretest questions to acquire posttest results or student abilities after using the trainer kit and VFD jobsheet. Furthermore, the average results of pretest and posttest scores will be compared using gain scores to find out how much the improvement in student learning outcomes after using VFD learning material and jobsheets.

2.2. Respondents

This study included a total of 130 respondents, comprising 122 vocational students, 1 industry expert/practitioner specializing in VFD, 1 instructor from a Vocational training center, 4 vocational teachers from different VSS in Cilegon City, Serang Regency, and Serang City in Banten, Indonesia, and 2 lecturers. The respondents were chosen by the purposive sampling technique [56], [57]. Excluded from consideration are data that fail to match the specified criteria. The specific criteria for identifying media experts, material experts, and users are outlined in Table 1. A validator is a specialist or practitioner who specializes in the construction of learning media products and with extensive knowledge in VFD learning material content.

Table 1. Criteria of validator and user respondents

No	Respondents	Criteria	Expertise
1	Validator of educational media	Possess expertise and practical knowledge in electronic control systems and/or the domain of educational media	Experts in the field of educational media and training kits
2		Possess expertise in creating trainer kits and educational materials specifically focused on VFD	
3		Must possess a minimum of 5 years of experience in the field of electrical engineering or have received formal education in electrical engineering.	
4		Minimum educational requirement: bachelor's degree.	
5	Validator of educational materials	Possess expertise and practical knowledge in electronic control systems and/or the domain of educational materials.	Experts in the field of educational materials
6		Possess a minimum of 5 years of professional experience as an educator, lecturer, or instructor specializing in the domain of electronic control systems.	
7		Must possess a minimum of 5 years of experience in the field of electrical engineering or have a background in electrical education.	
8		Minimum educational requirement: bachelor's degree.	
9	Users	Vocational students majoring in Industrial Electronics Engineering expertise	Trainer kit users

2.3. Collecting data

This study employed several data collection techniques, including: i) conducting interviews to identify the issues present in the field of industrial electronics engineering expertise at VSS State No. 1 Cilegon City; ii) utilizing the Likert scale questionnaire, which is a scale used to assess attitudes, opinions, and perceptions of individuals or groups regarding social phenomena [58]. In this study, the Likert scale was employed to measure the level of suitability of media and VFD learning jobsheets [59]; and iii) administering tests, which were divided into two parts: a pretest conducted prior to students using VFD learning media and jobsheets, and a posttest conducted after students had utilized VFD learning media and jobsheets.

2.4. Data analysis

This study employs various data analysis techniques, specifically: i) qualitative descriptive analysis, utilized to assess the feasibility of media and VFD learning jobsheets; ii) gain score, employed to measure the effectiveness of VFD learning media following student utilization; iii) the product moment is employed to validate questions intended for pretest and posttest. Validation is necessary to ensure that a research instrument accurately measures the intended variables [60]; and iv) the KR 20 is utilized to assess the reliability of questions for pretest and posttest. Reliability testing is conducted to ensure that the instrument consistently produces the same results when administered to the same subjects, even when tested at different times [60].

3. RESULTS AND DISCUSSION

Prior to student usage, it is necessary to conduct validity and reliability testing on the questions. To assess validity, researchers employed a sample of 17 participants and administered a set of 35 questions, each with 5 multiple-choice options. The questions were then analyzed using the product moment technique, and the resulting values were compared to the critical value in the r table. Questions are considered valid if their value exceeds the value of r [60] in this case, 16 valid questions were collected. Additionally, the researcher included 4 corrected questions, resulting in a total of 20 questions. Subsequently, the question's reliability was assessed using KR 20, yielding a result of 0.747. Referring to Table 2, this value falls into the "high" category, indicating that the test questions had a high level of reliability.

Table 2. The interpretation of reliability category

Value r	Interpretation
$0.80 < r_i \leq 1.00$	Very high
$0.60 < r_i \leq 0.80$	High
$0.40 < r_i \leq 0.60$	Moderate
$0.20 < r_i \leq 0.40$	Low
$r_i \leq 0.20$	Very low

Once the media and learning jobsheets have been created, the next crucial step is to assess their practicality. This evaluation aims to determine whether the media and learning jobsheets are appropriate for student use. The assessment of media feasibility and learning jobsheets is conducted through the use of questionnaires that employ a Likert scale ranging from 1 to 4. The average value of the responses is then calculated. Subsequently, the results are examined using procedures that convert quantitative data into qualitative data. The evaluation of VFD learning media encompasses several criteria, including security,

tidiness, size, display appeal, functionality, ease, benefits for learners, and benefits for teachers. The average number of media experts collected is $x=97.33$. Figure 2 shows the results of the media feasibility test. Figure 2(a) shows the feasibility evaluation scores from 3 media experts, while Figure 2(b) shows the feasibility scores based on evaluations from material experts.

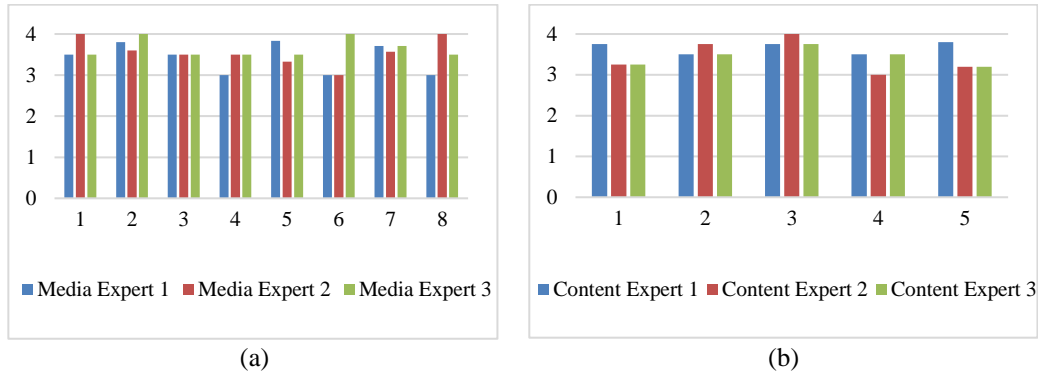


Figure 2. Feasibility test for (a) educational media and (b) content media

VFD trainer kits can be utilized without any inherent risks or potential hazards. The safety criteria and precautions established by Li and Wu [61], are followed, ensuring that all components in the VFD trainer kits are able to function correctly [62]. The VFD training kit is designed with exceptional structural integrity, featuring a robust frame and a clear, legible writing display. All components are meticulously arranged, ensuring the absence of any hazardous wires or components that may lead to a short circuit [63]. The installation of all these components complies with IEEE standards [61]. Additionally, the physical dimensions of this instructor have been modified to conform to the established norms in education, and have been enhanced to be visually appealing in order to encourage students' enthusiasm for learning in this VFD subject [64], [65].

Upon observation of Table 3, it is evident that the number 97.33 falls within the range of $x \geq 81$. This leads to the conclusion that the VFD learning media is highly suitable for student use, as it is deemed "highly feasible". Once the feasibility of the VFD learning media has been established, the next step is to assess the feasibility level of the VFD learning jobsheet. This assessment is based on several aspects: i) the accuracy of the material content, ensuring it is free from conceptual errors; ii) the alignment of the material with the learning objectives; iii) the practical benefits it offers for daily life; iv) the appropriateness of the material for students' abilities; and v) its ability to generate interest. The results of the assessment from material experts can be seen in Figure 2(b). The mean value of the three subject matter experts is $x=67$. Referring to Table 3, the value 67 falls within the range of $x \geq 57$, indicating that it can be inferred that the VFD learning jobsheet is very suitable for students.

According to the evaluation conducted by professionals, the feasibility test of VFD learning medium and jobsheets concluded that they are suited for research purposes, falling under the highly viable category. The average result of 100.91 was obtained based on the student replies as users of media and VFD learning jobsheets. By employing quantitative to qualitative data conversion techniques, it can be determined that the value of 100.91 falls within the range of $x \geq 90$. Therefore, it can be inferred that the utilization of VFD learning media and jobsheets elicits a highly favorable response from students. Once the media and jobsheet have been deemed viable by media experts and material specialists, the effectiveness of the media needs to be assessed on students. This is done by conducting pretest and posttest evaluations to measure student learning outcomes before and after utilizing VFD media and learning jobsheets. The study focused on a cohort of 22 individuals, whose average score on the pretest was 36.59, whereas their average score on the posttest was 82.5 as presented in Figure 3.

Table 3. Media and content validation score

No	Score	Score range	Category
1	$x \geq \bar{x} + 1.SBx$	$x \geq 81$	Highly feasible
2	$\bar{x} + SBx > x > \bar{x}$	$81 > x > 67.5$	Feasible
3	$\bar{x} > x \geq \bar{x} - 1.SBx$	$67.5 > x > 54$	Impracticable
4	$x < \bar{x} - 1.SBx$	$x < 54$	Highly impractical

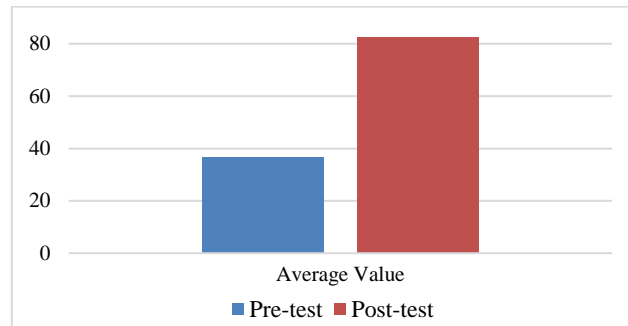


Figure 3. Average score pre-test and post-test

Nevertheless, this VFD learning media and jobsheet possess both benefits and drawbacks. The benefits of this VFD learning media are: i) the developed learning media includes a manual book that serves as a reference for using each component in this VFD learning media; ii) this learning media is equipped with a TDR that functions as a timer for students who wish to learn automatic electric motor installation using a timer; iii) the TOR (thermal overload relay) in this learning media is integrated with VFD components, facilitating students in creating a series of electric motor installations on this learning media; iv) the VFD in this learning media has a maximum capacity of 1.5kW, allowing it to be used with electric motors of up to 1.5 kW capacity; v) this VFD learning media is constructed using durable materials, ensuring its longevity and resistance to damage; vi) learning jobsheets serve as instructional guidance to assist students in utilizing VFD learning material and facilitate their practical work; and vii) Jobsheets are meticulously crafted, like professionally published books, featuring eye-catching covers to enhance their appeal. The VFD trainer kit is versatile and can be utilized to simulate and control numerous aspects of industrial manufacturing operations. Additionally, it might enhance students' knowledge on VFD [66]–[69].

The learning media has several disadvantages for future research: i) it lacks wheels, making it difficult for users to move it around; ii) the weight of the learning media is substantial when all panels are installed, making it challenging to move them individually; iii) there is only one electric motor available; and iv) the frame of the learning media body is not straight, so removing the leftmost or right panel requires starting with the middle panel and then shifting the leftmost panel to the middle position before it can be released. Several studies, one of which is by Suganob *et al.* [70] that only a few students experience difficulties in operating this trainer kit.

4. CONCLUSION

According to the performed research, the generated VFD learning media was deemed to be very feasible, with a score of 97.33 for VFD learning media and 67 for VFD learning jobsheets. The VFD learning medium and jobsheet garnered an excellent response from students, placing it in the "highly feasible" category. Furthermore, this VFD learning media and jobsheet demonstrate a significant level of efficacy in enhancing student learning outcomes, as evidenced by the gain score of 0.724, which falls within the "high effectiveness" category. Additionally, when comparing the average score of pretest results to the average score of posttest results, there is a remarkable increase. Therefore, it is necessary to increase the quantity of VFD learning media and jobsheets, as they have proven to be effective in enhancing student learning outcomes and developing their proficiency in controlling the speed of electric motors. This will help bridge the gap between the industry's skill requirements and the skills taught in schools.

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REFERENCES

- [1] M. A. Hamid, E. Permata, D. Aribowo, I. A. Darmawan, M. Nurtanto, and S. Laraswati, "Development of cooperative learning based electric circuit kit trainer for basic electrical and electronics practice," in *Journal of Physics: Conference Series*, 2020, vol. 1456, p. 12047, doi: 10.1088/1742-6596/1456/1/012047.

- [2] I. A. Darmawan *et al.*, "Electricity course on vocational training centers: a contribution to unemployment management," in *Journal of Physics: Conference Series*, Feb. 2020, vol. 1456, no. 1, p. 12048, doi: 10.1088/1742-6596/1456/1/012048.
- [3] X. Wang, J. Leng, X. Cong, and Z. Fan, "Development of junior high school students to secondary vocational students stigma scale," *Psychology Research and Behavior Management*, vol. 15, pp. 2957–2970, Oct. 2022, doi: 10.2147/PRBM.S381069.
- [4] A. W. Khurniawan, I. Sailah, P. Muljono, B. Indriyanto, and M. S. Maarif, "The improving of effectiveness school-based enterprise: a structural equation modeling in vocational school management," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 10, no. 1, pp. 161–173, Mar. 2021, doi: 10.11591/ijere.v10i1.20953.
- [5] A. W. Khurniawan, I. Sailah, P. Muljono, B. Indriyanto, and Ms. Maarif, "Strategy for improving the effectiveness of management vocational school-based enterprise in Indonesia," *International Journal of Education and Practice*, vol. 9, no. 1, pp. 37–48, 2021, doi: 10.18488/journal.61.2021.91.37.48.
- [6] S. Billett and C. Noble, "Utilizing pedagogically rich work activities to promote professional learning," *Éducation et didactique*, vol. 14, no. 14, pp. 137–150, Nov. 2020, doi: 10.4000/educationdidactique.7943.
- [7] S. Billett, S. Choy, and S. Hodge, "Enhancing the standing of vocational education and the occupations it serves: Australia," *Journal of Vocational Education and Training*, vol. 72, no. 2, pp. 270–296, Apr. 2020, doi: 10.1080/13636820.2020.1751247.
- [8] N. Kholifah, M. S. Kurdi, M. Nurtanto, F. Mutohhar, M. Fawaid, and T. S. Subramaniam, "The role of teacher self-efficacy on the instructional quality in 21st century: a study on vocational teachers, Indonesia," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 2, pp. 998–1006, Jun. 2023, doi: 10.11591/ijere.v12i2.23949.
- [9] S. Billett and F. Valencia-Forrester, "Post-practicum project: its educational purposes, importance, and roles," *Professional and Practice-based Learning*, vol. 28, pp. 3–23, 2020, doi: 10.1007/978-3-030-48062-2_1.
- [10] F. Mutohhar, M. B. Triyono, P. Sudira, M. Nurtanto, and N. Kholifah, "The role of entrepreneurial personality mediation and technological competencies moderation in determining entrepreneurial intentions in vocational education," *Journal of Technical Education and Training*, vol. 15, no. 1, pp. 128–141, 2023, doi: 10.30880/jtet.2023.15.01.012.
- [11] S. Choy, D. Dymock, L. Le, and S. Billett, "Understanding student decision-making about VET as a pathway: an Australian study," *International Journal of Training Research*, vol. 19, no. 2, pp. 125–141, 2021, doi: 10.1080/14480220.2021.1905684.
- [12] R. W. Daryono, M. A. Ramadhan, N. Kholifah, F. D. Isnantyo, and M. Nurtanto, "An empirical study to evaluate the student competency of vocational education," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 2, pp. 1079–1086, Jun. 2023, doi: 10.11591/ijere.v12i2.22805.
- [13] Directorate of Population and Labour Statistics Central Bureau of Statistics of the Republic of Indonesia, *Labor force situation in Indonesia August 2023 (in Indonesian)*. Jakarta: BPS-Statistics Indonesia, 2023. <https://www.bps.go.id/id/publication/2023/12/08/f8c567805aa8a6977bd4594a/labour-force-situation-in-indonesia-august-2023.html>
- [14] Central Bureau of Statistics of the Banten Province, *Labor force situation in Banten August 2023 (in Indonesian)*. BPS-Statistics Indonesia, 2023. <https://banten.bps.go.id/pressrelease/2023/11/06/752/keadaan-kegiatan-kerja-banten-agustus-2023.html>
- [15] L. M. Nurieva and S. G. Kiselev, "Employment of graduates of pedagogical universities: statistics vs mythology," *The Education and science journal*, vol. 22, no. 9, pp. 37–66, Nov. 2020, doi: 10.17853/1994-5639-2020-9-37-66.
- [16] A. K. Kusainov, K. A. Yessenova, R. S. Kassymova, K. S. Moldassan, and A. M. Sembayeva, "Comparative analysis of the process of training education managers in educational institutions," *International Journal for Research in Vocational Education and Training*, vol. 8, no. 2, pp. 186–207, Jul. 2021, doi: 10.13152/IJRVT.8.2.3.
- [17] S. Subekti, A. Ana, M. S. Barliana, and I. Khoerunnisa, "Problem solving improvement through the teaching factory model," *Journal of Physics: Conference Series*, vol. 1402, no. 2, p. 022044, Dec. 2019, doi: 10.1088/1742-6596/1402/2/022044.
- [18] S. L. Gupta, A. Mittal, S. Singh, and D. N. Dash, "Demand-driven approach of vocational education and training (VET) and experiential learning: a thematic analysis through systematic literature review (SLR)," *Asian Education and Development Studies*, Vol. 13 No. 1, pp. 45–63, 2024. <https://doi.org/10.1108/AEDS-07-2023-0083>.
- [19] M. Cholik, M. Samani, I. G. P. A. Buditjahjanto, and A. R. Putri, "The effect of education system components on the quality of vocational high school graduates," *International Journal of Instruction*, vol. 14, no. 3, pp. 24–254, Jul. 2021, doi: 10.29333/IJI.2021.14314A.
- [20] R. Oczkowska, S. Wisniewska, and P. Lula, "Analysis of the competence gap among vocational school graduates in the area of smart specialization in Poland," *International Journal for Quality Research*, vol. 11, no. 4, pp. 945–966, 2017, doi: 10.18421/IJQR11.04-14.
- [21] Minister of Manpower of the Republic of Indonesia, Decree of the Minister of Manpower of the Republic of Indonesia Number 398 of 2014 concerning the Establishment of Indonesian National Work Competency Standards for the Category of Processing Industries of the Main Groups of the Rubber Industry. Indonesia: <https://jdih.kemnaker.go.id/katalog-1036-Keputusan%20Menaker.html.html>, 2014.
- [22] A. Rahmat, A. R. Nugroho, A. Saregar, M. A. Hamid, M. R. N. Prastyo, and A. Mutolib, "Small hydropower potential of rivers in Sukabumi Regency, West Java, Indonesia," *Journal of Physics: Conference Series*, vol. 1155, no. 1, p. 012041, Feb. 2019, doi: 10.1088/1742-6596/1155/1/012041.
- [23] Minister of Manpower of The Republic of Indonesia, Decree of the Minister of Manpower Number KEP.268/MEN/VI/2007 concerning the Establishment of Indonesian National Work Competency Standards for the Electricity Sector of the Electricity Sub-Sector in the Field of Electric Power Distribution. Indonesia: <https://jdih.kemnaker.go.id/katalog-700-Keputusan%20Menakertrans.html.html>, 2007.
- [24] R. X. Perez, "Operating centrifugal pumps with variable frequency drives in static head applications," in *Condition Monitoring, Troubleshooting and Reliability in Rotating Machinery*, Wiley, 2023, pp. 353–362. doi: 10.1002/9781119631620.ch17.
- [25] M. R. Semsar, S. M. H. Hosseini, S. B. Mozaffari, and S. E. Afjei, "A novel topology of drive & thermal model for variable speed pump-storage power plant," *Journal of Energy Storage*, vol. 73, p. 108818, Dec. 2023, doi: 10.1016/j.est.2023.108818.
- [26] S. U. Khan *et al.*, "Control motor speed through variable frequency drive by using Arduino," in *AIP Conference Proceedings*, 2023, p. 040008, doi: 10.1063/5.0124533.
- [27] P. Surana, K. Gopakumar, L. Umanand, K. Rajashekara, and L. G. Franquelo, "A variable speed induction motor drive with 24-stepped voltage waveform throughout modulation range," *IEEE Transactions on Industrial Electronics*, vol. 71, no. 2, pp. 1268–1276, Feb. 2024, doi: 10.1109/TIE.2023.3260354.
- [28] Y. Ali, M. P. H. Raadsen, and M. C. J. Bliemer, "Modelling speed reduction behaviour on variable speed limit-controlled highways considering surrounding traffic pressure: a random parameters duration modelling approach," *Analytic Methods in Accident Research*, vol. 40, p. 100290, Dec. 2023, doi: 10.1016/J.AMAR.2023.100290.
- [29] L. Schibuola, M. Scarpa, and C. Tambani, "Variable speed drive (VSD) technology applied to HVAC systems for energy saving: an experimental investigation," *Energy Procedia*, vol. 148, pp. 806–813, 2018, doi: 10.1016/j.egypro.2018.08.117.

- [30] A. Cortinovis, D. Pareschi, M. Mercangoez, and T. Besselmann, "Model predictive anti-surge control of centrifugal compressors with variable-speed drives," in *IFAC Proceedings Volumes*, 2012, pp. 251–256. doi: 10.3182/20120531-2-NO-4020.00052.
- [31] V. Vodovozov, Z. Raud, and L. Gevorkov, "PLC-Based pressure control in multi-pump applications," *Electrical, Control and Communication Engineering*, vol. 9, no. 1, pp. 23–29, 2015, doi: 10.1515/ecce-2015-0008.
- [32] R. M. Branch, *Instructional design: the ADDIE approach*. Boston, MA: Springer US, 2009, doi: 10.1007/978-0-387-09506-6.
- [33] W. D. Mulyono, Suparji, A. Wardhono, and G. A. Y. P. Adistana, "The influence of communication and teamwork skills on the work readiness of vocational high school students," *World Transactions on Engineering and Technology Education*, vol. 21, no. 3, pp. 199–204, 2023.
- [34] M. A. Ramadhani and E. Rahayu, "Competency improvement through internship: an evaluation of corporate social responsibility program in vocational school," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 3, pp. 625–634, Sep. 2020, doi: 10.11591/ijere.v9i3.20571.
- [35] L. Zhou and M. Preindl, "Variable switching frequency techniques for power converters: review and future trends," *IEEE Transactions on Power Electronics*, vol. 38, no. 12, pp. 15603–15619, Dec. 2023, doi: 10.1109/TPEL.2023.3317232.
- [36] I. M. Putrama, M. W. A. Kesiman, N. Sugihartini, and L. P. E. Damayanthi, "Developing jobsheet for basic programming based on performance assessment," *Journal of Physics: Conference Series*, vol. 1516, no. 1, Jun. 2020, doi: 10.1088/1742-6596/1516/1/012039.
- [37] T. W. Saputra and Wagiran, "Developing project-based learning model using jobsheet in vocational high school," *Journal of Physics: Conference Series*, vol. 1273, no. 1, Nov. 2019, doi: 10.1088/1742-6596/1273/1/012041.
- [38] F. Prasetya, B. R. Fajri, and F. Ranuharja, "Development design augmented reality-based jobsheet in CNC programming subjects," *International Journal of Innovation, Creativity and Change*, vol. 10, no. 11, pp. 50–67, 2020.
- [39] Purnamawati, U. Mulbar, and G. D. Dirawan, "Analysis on instructional design instruments of metacognition based electronic industries expertise in vocational schools," *Journal of Engineering and Applied Sciences*, vol. 13, no. 11, pp. 4125–4130, 2018, doi: 10.3923/JEASCI.2018.4125.4130.
- [40] S. Fuada, H. Elmunsyah, and Suwasono, "Design and fabrication of LC-Oscillator tool kits based Op-Amp for engineering education purpose," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 1, no. 1, pp. 88–100, Jan. 2016, doi: 10.11591/IJEECS.V1.I1.PP88-100.
- [41] F. N. Aziz and Mashoedah, "Development of training kit basic aerial robotics using RC plane robot for robotics course," *Journal of Physics: Conference Series*, vol. 2111, no. 1, Dec. 2021, doi: 10.1088/1742-6596/2111/1/012027.
- [42] M. C. Hsieh, "Portfolio assessment: reliability and validity in school management," *Bulletin of Educational Psychology*, vol. 54, no. 2, pp. 333–356, 2022, doi: 10.6251/BEP.202212_54(2).0004.
- [43] Y. H. Lee, Y. T. Chou, and Y. T. Sung, "Development and validation of a diagnostic assessment of chinese competence system," *Bulletin of Educational Psychology*, vol. 53, no. 2, pp. 285–306, Dec. 2021, doi: 10.6251/BEP.202112_53(2).0002.
- [44] B. Pollard, M. F. J. Fox, L. Ríos, and H. J. Lewandowski, "Creating a coupled multiple response assessment for modeling in lab courses," in *2020 Physics Education Research Conference Proceedings*, Sep. 2020, pp. 400–405, doi: 10.1119/perc.2020.pr.Pollard.
- [45] Muthmainnah and E. Istiyono, "Constructing reasoning multiple choice test to measure bloomian higher order thinking skills in physics of XI grade students," *Journal of Physics: Conference Series*, vol. 1233, no. 1, p. 012037, Jun. 2019, doi: 10.1088/1742-6596/1233/1/012037.
- [46] L. Matosas-López, J. C. Aguado-Franco, and J. Gómez-Galán, "Constructing an instrument with behavioral scales to assess teaching quality in blended learning modalities," *Journal of New Approaches in Educational Research*, vol. 8, no. 2, pp. 142–165, 2019, doi: 10.7821/naer.2019.7.410.
- [47] M. A. Hamid, S. A. Rahman, I. A. Darmawan, M. Fatkhurrohman, and M. Nurtanto, "Performance efficiency of virtual laboratory based on unity 3D and blender during the COVID-19 pandemic," *Journal of Physics: Conference Series*, vol. 2111, no. 1, p. 012054, Nov. 2021, doi: 10.1088/1742-6596/2111/1/012054.
- [48] T. H. T. Maryadi, A. S. J. Wardhana, E. S. Damarwan, and T. Sukisno, "Performance of frequency regulation on power in the development of variable speed drive training kit as a learning media for motor control practices," *Journal of Physics: Conference Series*, vol. 2111, no. 1, p. 012036, Nov. 2021, doi: 10.1088/1742-6596/2111/1/012036.
- [49] N. A. Ojeda-Aguirre, A. Garcia-Perez, R. de J. Romero-Troncoso, D. Morinigo-Sotelo, O. Duque-Perez, and D. Camarena-Martinez, "Reassigned short time fourier transform and K-means method for diagnosis of broken rotor bar detection in VSD-fed induction motors," *Advances in Electrical and Computer Engineering*, vol. 19, no. 2, pp. 61–68, 2019, doi: 10.4316/aece.2019.02008.
- [50] A. Harvey *et al.*, "Evaluation of a media training workshop for nutrition students and trainees in Nova Scotia," *Canadian Journal of Dietetic Practice and Research*, vol. 84, no. 2, pp. 112–118, Jun. 2023, doi: 10.3148/cjdp-2022-036.
- [51] N. Yuniarti, A. L. Setiawan, and D. Hariyanto, "The development and comprehensive evaluation of control system training kit as a modular-based learning media," *TEM Journal*, vol. 9, no. 3, pp. 1234–1242, Aug. 2020, doi: 10.18421/TEM93-52.
- [52] B. Cleveland and K. Fisher, "The evaluation of physical learning environments: a critical review of the literature," *Learning Environments Research*, vol. 17, no. 1, pp. 1–28, Apr. 2014, doi: 10.1007/S10984-013-9149-3.
- [53] P. F. Torres *et al.*, "A mobile educational tool designed for teaching and dissemination of grid connected photovoltaic systems," *Computers & Electrical Engineering*, vol. 76, pp. 168–182, Jun. 2019, doi: 10.1016/j.compeleceng.2019.03.017.
- [54] E. Yafie, Z. M. Ashari, N. A. Samah, D. Setyaningsih, D. P. Wahyuningtyas, and I. G. L. A. Wiranata, "Development of SMART-P to improve parental locus of control and children's social-emotional development," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 13, no. 2, pp. 876–891, Apr. 2024, doi: 10.11591/ijere.v13i2.26503.
- [55] I. Wardani, H. Tolle, and I. Aknuranda, "Evaluation of an educational media on cube nets based on learning effectiveness and gamification parameters," *International Journal of Emerging Technologies in Learning (IJET)*, vol. 14, no. 14, pp. 4–18, Jul. 2019, doi: 10.3991/ijet.v14i14.10505.
- [56] M. J. Barratt, J. A. Ferris, and S. Lenton, "Hidden populations, online purposive sampling, and external validity: taking off the blindfold," *Field Methods*, vol. 27, no. 1, pp. 3–21, Feb. 2015, doi: 10.1177/1525822X14526838.
- [57] S. Campbell *et al.*, "Purposive sampling: complex or simple? Research case examples," *Journal of Research in Nursing*, vol. 25, no. 8, pp. 652–661, Dec. 2020, doi: 10.1177/1744987120927206.
- [58] M. A. Hamid, A. Aribowo, and Desmira, "Development of learning modules of basic electronics-based problem solving in vocational secondary school," *Jurnal Pendidikan Vokasi*, vol. 7, no. 2, pp. 149–157, Jul. 2017, doi: 10.21831/jpv.v7i2.12986.
- [59] M. A. Hamid, L. Yuliawati, and D. Aribowo, "Feasibility of electromechanical basic work e-module as a new learning media for vocational students," *Journal of Education and Learning (EduLearn)*, vol. 14, no. 2, pp. 199–211, May 2020, doi: 10.11591/edulearn.v14i2.15923.




- [60] L. Fendler, "Ethical implications of validity-vs.-reliability trade-offs in educational research," *Ethics and Education*, vol. 11, no. 2, pp. 214–229, May 2016, doi: 10.1080/17449642.2016.1179837.
- [61] S. Li and X. Wu, "A functional safety assessment methodology for explosion protection with application to a variable frequency drive system," *Energies*, vol. 14, no. 23, p. 7872, Nov. 2021, doi: 10.3390/en14237872.
- [62] D. Bordeasu, O. Prostean, I. Filip, and C. Vasar, "Adaptive control strategy for a pumping system using a variable frequency drive," *Machines*, vol. 11, no. 7, p. 688, Jun. 2023, doi: 10.3390/machines11070688.
- [63] S. N. Patrialova, D. H. Wardhana, L. P. Rahayu, and T. Agasta, "The characteristic of variable frequency drive for water flow control in the SFC plant," *IPTEK The Journal of Engineering*, vol. 7, no. 1, pp. 6–10, Apr. 2021, doi: 10.12962/j23378557.v7i1.a8415.
- [64] J. R. Mahmood and R. S. Ali, "Personal computer/programmable logic controller based variable frequency drive training platform using WxPython and PyModbus," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 4, pp. 3564–3571, Aug. 2022, doi: 10.11591/ijece.v12i4.pp3564-3571.
- [65] Suyitno, D. Jatmoko, A. Susanto, A. Primartadi, and T. Mahfud, "Trainer stand instructional media of wiring system for kijang car to improve student achievement in vocational higher education," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 11, no. 11, pp. 991–997, Nov. 2019, doi: 10.5373/JARDCS/V11SP11/20193126.
- [66] P. Chakraborty, A. Hossain, and V. Pillarisetty, "Designing and assembling of a programmable logic controls (PLC) laboratory trainer and advanced research setup," in *2016 ASEE Annual Conference & Exposition Proceedings*, 2016, pp. 1–14, doi: 10.18260/p.26701.
- [67] D. Jatmoko *et al.*, "The factors influencing digital literacy practice in vocational education: a structural equation modeling approach," *European Journal of Educational Research*, vol. 12, no. 2, pp. 1109–1121, Apr. 2023, doi: 10.12973/eu-jer.12.2.1109.
- [68] M. Nurtanto, P. Sudira, H. Sofyan, N. Kholifah, and T. Triyanto, "Professional identity of vocational teachers in the 21st century in Indonesia," *Journal of Engineering Education Transformations*, vol. 35, no. 3, pp. 30–36, Jan. 2022, doi: 10.16920/jeet/2022/v35i3/22085.
- [69] Rabiman, P. Sudira, H. Sofyan, and M. Nurtanto, "Practical learning media in subject maintenance of chassis and power (MCP) based online: simple learning using videos on YouTube," *International Journal of Interactive Mobile Technologies (IJIM)*, vol. 15, no. 3, pp. 130–145, Feb. 2021, doi: 10.3991/ijim.v15i03.14943.
- [70] N. J. Sukanob *et al.*, "Design and development of mechatronics trainer for skills competency assessment," in *2022 IEEE 14th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, Dec. 2022, pp. 1–6, doi: 10.1109/HNICEM57413.2022.10109540.

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